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Method for power optimization in a vehicle/ train having an efficiency that depends on the operating point

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Method for power optimization in a vehicle/train having an efficiency that depends on the operating point

Sub A1 ~~Description~~

The invention relates to a method for power optimization in a vehicle/train according to the preamble of claim 1.

Ins A2

During the planning of journeys and the drafting of schedules for rail traffic, time reserves for unforeseen events and adverse operating conditions are included in the plans. Since, during real journeys, the operating conditions are typically more favorable than those assumed during planning, the time reserves created by this are available for other purposes. A particularly practical use of the time reserves resides in the saving of power by means of a suitable travel mode.

Previously known and used methods for power minimization are mostly based on the assumption that a travel mode comprising the constituents maximum acceleration - travel at constant speed - coasting - maximum retardation is optimum in power terms. In this case, the mechanical tractive power which is needed to accelerate the vehicle is minimized. For verification, a linear dynamic train model is used, in particular no account being taken of any term which describes the quadratic relationship between speed and travel resistance.

In DD 255 132 A1, this basic assumption is expanded by subdividing a total route into a number of sections, so that in each section the slope resistance of the route is constant.

In EP 0 467 377 B1, the subdivision of the overall route into a number of sections is introduced in such a way that in each section the permissible maximum speed is constant. The travel mode comprising the constituents maximum acceleration - travel at constant speed - maximum retardation is repeated in each section. Coasting is therefore dispensed with.

EP 0 755 840 A1 does not describe a practical method for power optimization but instead explains a general system structure with which power optimization can also be implemented. A cycle comprising acceleration - travel at constant speed - retardation and braking is listed as an example.

Ins A15

The invention is based on the object of specifying an improved method for power optimization with regard to the time reserves included in the planning of a schedule of a vehicle/train.

This object is achieved, in conjunction with the preamble, by the features specified in claim 1.

The advantage which can be achieved by the invention is in particular that, by taking into account the dependence of the vehicle efficiency on the operating point in the optimization algorithm, instead of the mechanical tractive power, it is the power primarily used, such as the electrical power in electric rail vehicles, which is minimized.

An advantageous refinement of the invention is identified in the subclaim.

Further advantages of the proposed method emerge from the following description.

The invention will be explained in more detail below using the exemplary embodiments illustrated in the drawing, in which:

Figs. 1, 2 show characteristic maps of the power loss of typical electric locomotives,

Fig. 3 shows an exemplary speed plot at an assumed constant vehicle efficiency and maximum speed, and

Fig. 4 shows an exemplary optimum speed plot taking into account the dependence of the vehicle efficiency on the operating point, and maximum speed.

The vehicle efficiency is the ratio between the tractive power provided - the output power - and the input power needed for this, in particular the electric power, which is drawn by an electric locomotive via a pantograph. The difference between the input power and the output power is the power loss of the vehicle.

The invention provides for the dependence of the efficiency on the operating point to be included in the power optimization or for power optimization with regard to the time reserves included in the planning of a schedule of a vehicle/train, since a calculation with an assumed constant efficiency represents only a poor approximation to the actual optimum. In this case, the problem of power minimization is formulated as a mathematical optimization problem and is solved by a suitable, generally known optimization algorithm.

Optimization algorithms which are suitable for the proposed method are known, for example, from Papageorgiou: Optimierung [Optimization], Chapters 10, 19 and in particular 20, Oldenbourg Verlag, 1996.

The dependence of the efficiency on the operating point can be taken into account via a function of the efficiency or the power loss as a function of important influencing variables, such as in particular the tractive force and/or speed and/or temperature. For this purpose, Figures 1 and 2 show characteristic maps of the power loss of typical electric locomotives. Such a three-dimensional characteristic map of the power loss as a function of the tractive force and the speed is a typical option for representing the dependence of the efficiency on the operating point.

Fig. 3 shows, as a traveling diagram, an exemplary distance/speed plot - see the continuous curve - with an assumed constant vehicle efficiency and maximum speed in the individual route sections - see the dashed curve. The travel mode illustrated is composed of the known constituents, these being used repeatedly in each subsection with constant speed limitation. These known constituents are essentially maximum acceleration, coasting and braking in the first section, followed by "travel at constant speed" in the slow-travel section, followed by maximum acceleration and the change between coasting and braking to a standstill.

Fig. 4 shows, in comparison with this, as a travel diagram (and determined in accordance with the characteristic map according to Fig. 1) an exemplary optimum speed plot - see continuous curve - taking into account the dependence of the vehicle efficiency on the operating point and maximum speed - see the dashed curve. The optimum travel mode illustrated differs considerably from ~~travel modes~~ which can be determined with previously known methods (see Fig. 3). In particular, in the exemplary embodiment illustrated, use is made of reduced acceleration, which merges smoothly into the braking.